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Secondary Recycling of Smelter Slags

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Abstract

The modern structure of ferrous metallurgy slags recovery has been shown. Growth of recycling amounts is connected with high-capacity stationary and mobile crushing and screening plants (both foreign- and domestic made). The issues of environment protection against dust emissions still remain unsolved.

Keywords: smelter slags, recycling technologies, crushing and screening plants, extraction and cleaning of metal inclusions.

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There are two basic stages – primary and secondary – which are singled out in the technology of smelter slags recycling, both in Russia and abroad. The primary stage includes removing of slag from melting units; rolling-over of melt from the slag yard into a special pit or a waste dump; slag cooling; oversize breakdown; extraction of large metal inclusions. The secondary stage (recycling) usually includes of slag into motor vehicles and its delivery to crushing and screening plants (CSP); slag recycling at CSP, including: pre-screening of slag, oversize screening and breakdown; extraction of metal inclusions; manual taking out of non-magnetic and other valuable components from the slag flow; slag crushing in one or multiple stages; pre-crushing and control screening of the crushed slag; cleaning of slaggy scrap taken out from the slag and its further screening; protection against dust emission, dust oppression and dust catching.

It is conventional technological devices and equipment that prevail on the stage of primary recycling of slag; but secondary recycling was significantly altered in recent times due to implementation of high-capacity domestic- and foreign-made crushing and screening aggregates and field plants. Until 1960s, recycling of slags was not practically performed at national plants, the most of slag masses were removed to dump piles. Banded slag matured in dump piles was used for bedding of roads, backfills, etc. The first large-scale slag-processing shop was built on Novolipetsky Metallurgical United Works. Domestic-made crushing and screening equipment was installed in the shop borrowed from various industry branches. The technology of converter slags recycling was elaborated by the personnel of Ural Institute of Metals. Of issue were problems

of oversize crushing and protection of crushers against ingress of uncrushable bodies and dust removal [1].

According to the technological work statement of UIM JSC, one of the first movable CSPs on basis of mobile equipment (PDSU-2) of Vyksa Plant of size reduction equipment was built at Alapayevsk Metallurgical United Works. Primary crushing was performed in SMD-110 crusher and secondary in SMD-108 packaged unit. The similar plants were built on Zlatoust, Nizhne-Serginsky and Lysva metallurgical plants. According to this technology, a stationary plant for recycling of dump pile slags is operated on Seversky Pipe Plant, with the design capacity of 300.000 tons per year. On Serov Metallurgical Plant, *Magnet* firm operates a unit for slag recycling with extraction of metal inclusions and producing commercial fractions of slag crushed stone and sand, with use of elements of movable units and SMD-111 coarse crusher of Volgotsemmash Plant. Metal is picked up by hoisting electric magnets, suspended and pulley iron separators made by Dynamo Plant. The listed installations were designed according to technological work statements of UIM JSC. The experience of assimilation of slag recycling units allowed the institute to develop a type process design assignment for crushing and screening units with capacity from 50 thousand tons to 3 million tons per year [2].

In the shop for recycling of technogenetic wastes of Nizhny Tagil Metallurgical United Works (capacity 3 million tons per year), for the first time in Russia, West Germany-made equipment was used for slag recycling, whereon dump piles of steelmaking slags in amount over 20 million tons were practically entirely recycled.

At present, under conditions of the current market the most popular for slag recycling are installations made by AMCOM LLC USA [3]. They are operated on Magnitogorsk Metallurgical United Works (3 sets), on Novolipetsk United Works (1 set), and on Chelyabinsk United Works (1 set).

An installation for recycling of metallurgical production dump pile slags is designed for scrap extraction and for producing of fractioned break-stone with capacity 300 tons per hour (Fig. 1). The following machines are used as extraction-and-loading and transport equipment for development of slag dump piles: two excavators KOMATSU PC450 (included into the delivery set), back shovel, bucket 2.2 – 3.0 m^3, dump trucks KrAZ, MAZ, BelAZ, etc. The AMCOM installation includes the following units:

- *screen* is an important components of the installation; it is a structure with a vibro-drive designed for screening of slag into fractions by screening it through sieves. When selecting a model, the following parameters should be considered: number of sieves, productivity, sieve mesh size, motor power;

- *manual take-out station* is a closed heated room with a conveyor inside. The conveyor band speed does not exceed 0.5 m/s, which allows efficiently perform manual taking out of materials which are valuable for production;

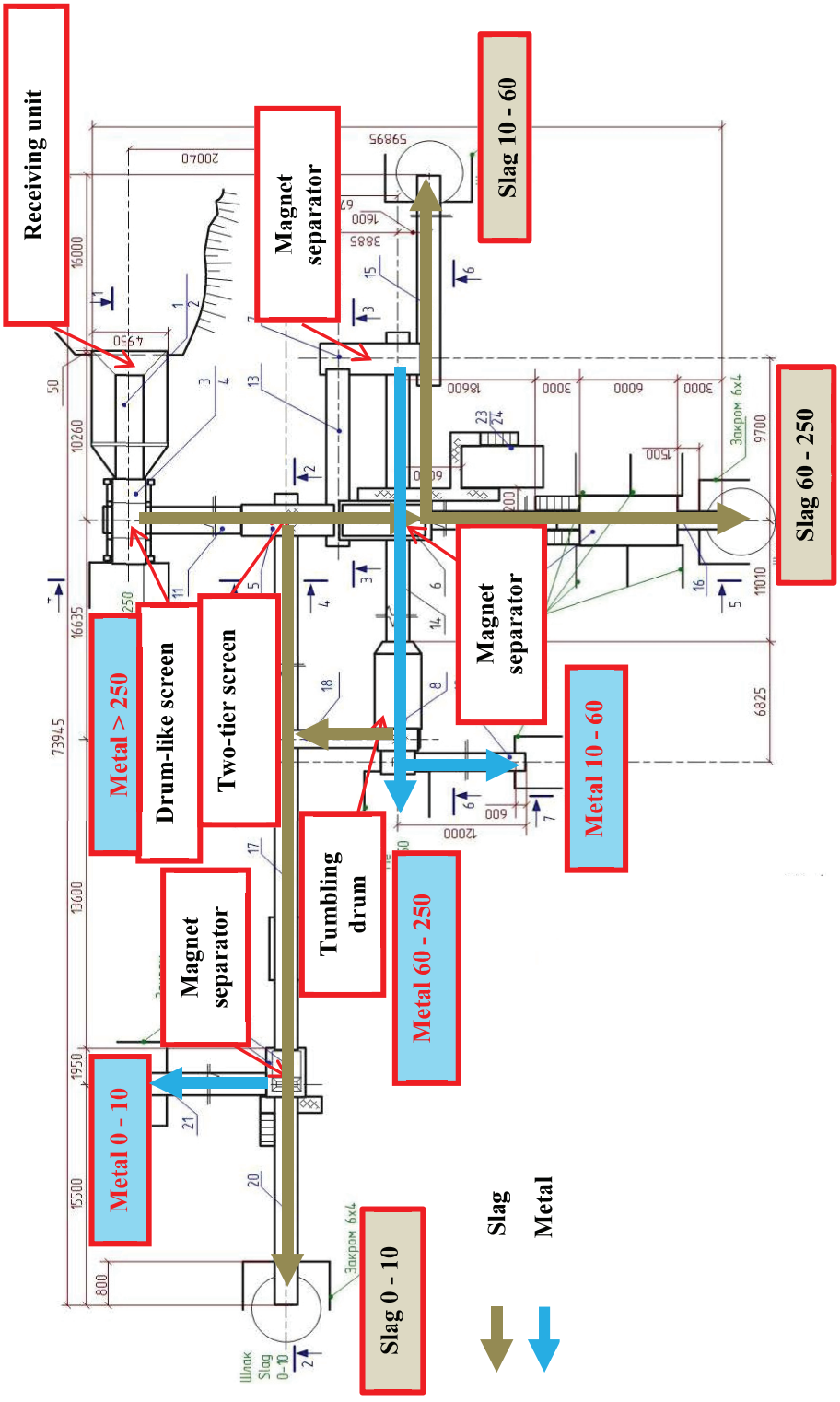

Figure 1: Block diagram of units of AMCOM installation

- *magnet separator* for extraction of ferromagnetic inclusions contains the permanent magnet segment. The segment position inside the drums shall determine purity of the metal-containing product sampling;

- *tumbling drum* performs additional cleaning of scrap from slag impurities. The material of 10-60 mm and 60-250 mm fractions passes cleaning therein. The technological process involves friction and beating of the metal product particles about one another. The drum rotation frequency is regulated; further on, this frequency influences the degree of cleaning.

The set is equipped with an automated system of control via an operator's cabin. This process unit is a room with a control and video monitoring desk, which determines a high degree of the production process safety.

Cherepovets Metallurgical United Works *Severstal* cooperates with Finnish enterprises – producers of crushing and screening equipment. In 2014, a new crushing and screening plant (CSP) for slag recycling was commissioned in the united works. Supply of the basic process equipment for the project, erection supervision works and personnel training were performed by Ecofer Investment Oy (Finland). The amount of slag recycling on the installation exceeds 2.0 million tons per year. The CSP allows to produce construction break-stone of various fractions (0–5 mm, 5–20 mm and 20–40 mm) with the metallized particles content not over 5 %, that is, with improved physic-mechanical properties (Fig. 2) [4].

Figure 2: A view of the crushing and screening plant for smelter slag recycling on Severstal United Works

A number of enterprises for recycling of dump pile slags use self-moving packaged sets. To recycle dump pile slags of Beloretsky Metallurgical Plant, the investors purchased a packaged set produced by Power Pack Minerals (North Ireland) with productivity 150 t/hour (Fig. 3).

Figure 3: The crushing and screening plant for recycling of dump pile slags of Beloretsky Metallurgical Plant

AMZ-Tekhnogen Company utilizes packaged sets made by SANDVIK for recycling of dump pile slags. Such packaged sets are operated on Revda Metalware-Metallurgical Plant, Pervouralsk pipe plant and Kuznetsk Metallurgical United Works (Fig. 4).

Figure 4: Self-moving packaged set SANDVIK

Technological sets for slag recycling which are produced by Russian enterprises are in process of improvement. Fig. 5 shows a block diagram of the CSP units chain on basis of the movable equipment of Drobmash Closed Joint Stock Company with production capacity 1 million tons/year [5]. The installation is equipped with magnet separators, it extracts ferromagnetic metal inclusions and provides protection of crushers against ingress of uncrushable bodies. Screening aggregates ensure producing of standard ranges of slag break-stone fractions.

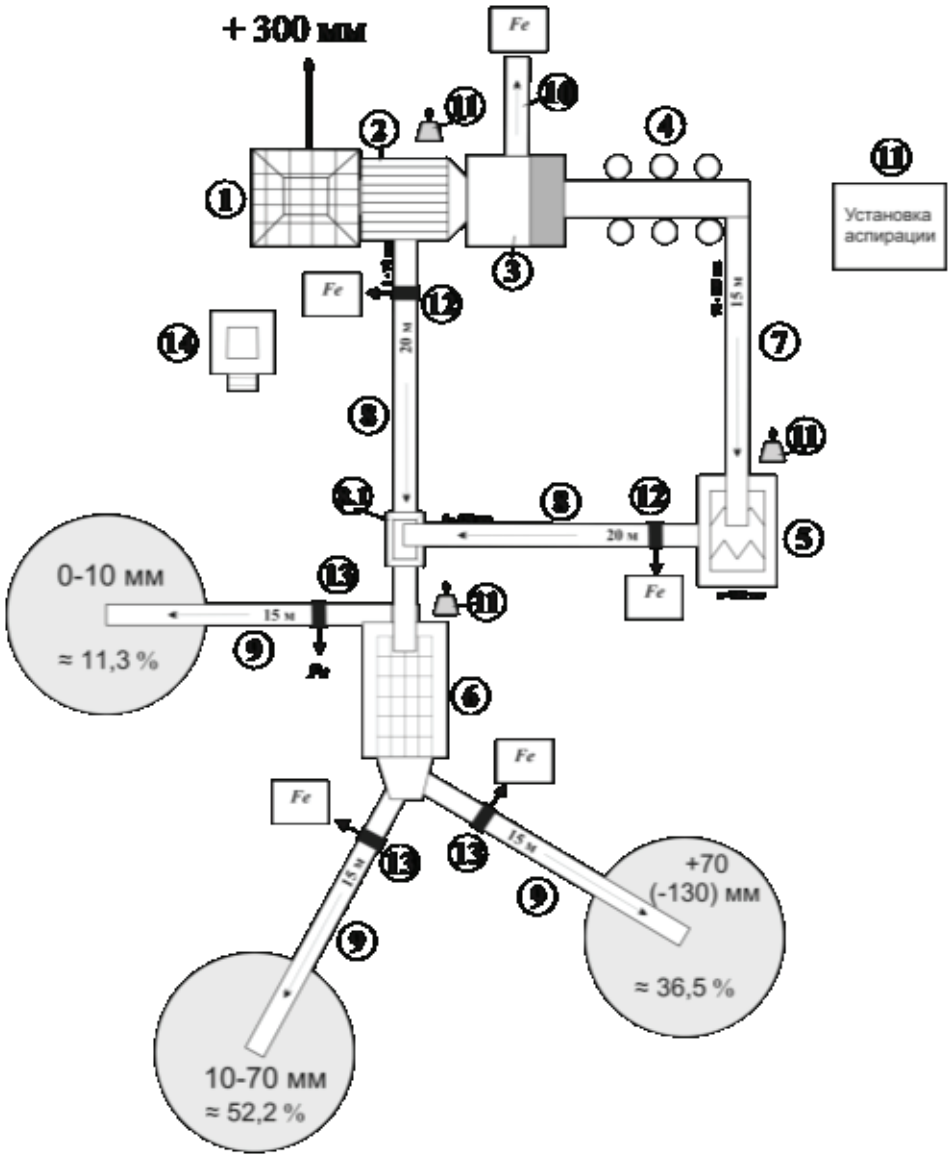

Figure 5: Block diagram of items of the installation for recycling of dump pile slags, productivity 150 t/hour, on basis of movable equipment. 1 – Vibro-feeder with properly-sized grill 300x300 mm; 2 – screening unit of DRO-654 (crushing and screening equipment); 3 – separation unit Ø 1250x1200 (LP) *Erga*; 4 – manual take-out station; 5 – coarse crushing unit DRO-721 (or SMD-510-30); 6 – screening unit with GIS-52, sieves – 70x70 mm and 10x10 mm on basis of DRO-690-70; 7 – conveyor, B=800 mm, L=15 m; 8 – conveyor, B=800 mm, L=20 m; 9 – conveyor, B=650 mm, L=15 m; 10 – conveyor, B=800 mm, L=10 m; 11 – aspiration unit; 12 – iron separator with receiving hopper for magnet product; 13 – iron separator with receiving hopper for magnet product; 14 – control unit U 7810.4A.

Kanmash DSO LLC (the city of Cheboksary) [6] in Lipetsk Region performed a successful commissioning of a crushing and screening plant in semi-mobile version for recycling of smelter slags with max. coarseness to 450 mm. The plant includes: unit for loading and crushing PREMIER with roller screen-feeder, jaw crusher KM DShch-5x9 and unloading conveyor; sorting unit with inertia screen KM GIS-53; a set of band

conveyors; cabin and control system. Due to the innovation layout of the roller screen-feeder and the jaw crusher on one frame, it occurred to be possible to raise the overall productivity of the process line to 150 tons/hour (~ 1 million tons/year), as pre-sorting of initial material takes place at the stage of its loading into the hopper, and only oversize (coarse) material is delivered to the jaw crusher. Thanks to this layout, wear of crushing surfaces is significantly reduced and there is possibility to regulate the jaw clearance down to minimal values (for increasing of output percentage of 5...20 mm and 20...40 mm fractions). Loading of the initial material can be performed with a loader or excavator, both from the rear and lateral side of the primary unit. The number of commercial fractions: 4. The set is operated by an operator from the desk in the control cabin. Mounting and adjustment of the whole set take less than 2 weeks, as the set was supplied by Customer by large-size aggregate units semi-assembled. The slag recycling set does not require conducting of any grave foundation works. All aggregates of the set are mounted on skids.

Taking into account elevated requirements to the metal product extracted from slags, the equipment stock for scrap cleaning has been expanded. Along with domestic-made drum tumblers and type impact crushers, German firm *Standart* offers special crushers which are able to accept slaggy scrap with coarseness to 700 mm and purge it from the slaggy component by means of a special drive of the crusher's movable jaws (Fig. 6). On the inner market, the equipment for slag recycling is presented by firm *Ecoprom* [7].

Figure 6: Installation for cleaning of slaggy scrap

In 2018, according to the statement of work from NLMK PJSC, Ural Institute of Metals developed pre-project solutions of process variants of recycling of the united works' old dump heaps with the further reclamation thereof [8]. It was proposed to include domestic- and foreign made equipment in crushing and screening installations. The economic appraisal of the variants showed advantages of applying of the equipment manufactured on Russian machine-building plants because of relatively small prices and inexpensive maintenance in the process of operation.

Thus, by now in the practice of secondary recycling of slags the stock of process equipment has been considerably upgraded, which allows not only to process large amounts of slags but also produce a wide assortment of high-quality products for civil engineering and metallurgical production.

The general disadvantage of secondary recycling of slags is a poor environmental protection against dust emissions, which causes necessity of searching of new ways to solve this task because of increased demands from supervisory authorities and the society.

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